The Role of Aesthetics in Engineering Design – Insights Gained from Cross-cultural Research into Traditional Fishing Vessels in Indonesia

Richard Birmingham
Marine, Offshore and Subsea Technology Group, School of Engineering, Newcastle University, Newcastle upon Tyne, UK

I Putu Arta Wibawa
Politeknik Perkapalan Negeri Surabaya, Jl. Teknik Kimia, Kampus ITS Sukolilo – Surabaya, Indonesia

ABSTRACT: The design of a small fishing vessel for the coastal waters of Indonesia is a straight forward technical challenge, however some initiatives to introduce newly designed vessels with more advanced technology have been unsuccessful. The observation that the appearance of rejected craft contrasts markedly with the traditional vessels operating in the area has led to the consideration of the importance of aesthetics in engineering design that is reported in this paper. Definitions of beauty, their relevance to engineering design, and alternative approaches to decisions regarding form and style are discussed, with examples taken from the marine domain. A proposal to make explicit the place of aesthetics in one theoretical model of the design process is followed by a description of the design of a fishing vessel for eastern Java, this being an example of cross-cultural design in practice, where aesthetics was given a prominent role.

1 INTRODUCTION

The products of engineering design, due to their size or location, can have a significant impact on the visual experience of those who are operating them, and on those living or working in relatively close proximity. Despite this the role of aesthetics in the design process is not always considered in any detail, and can even be ignored entirely. In the maritime sector a range of cases can be found, from the design of a luxury yacht at one extreme, where style can be elevated to the most important design driver, to the design of an offshore oil platform at the opposite extreme, where appearance might be considered an irrelevance. However even in an entirely functional artefact, such as a cargo ship, anecdotal evidence suggests that there is value in a product that is pleasing to the senses, one example (described informally by an ex-mariner, Dr Kayvan Pazouki, 2016) being the preference of a company's seagoing personnel to work aboard the oldest ship in the fleet, despite its poorer reliability, simply because its more traditional lines and style gave them greater pride in their work. Despite this evident pleasure afforded to the operators working aboard a vessel that had acknowledged aesthetic merit, to include such a subtle and esoteric benefit into calculations, and to establish the added value in cash terms, would be an almost impossible task.
Fishing vessels would conventionally be put into the same category as cargo ships, in terms of the unimportance of aesthetics in a design task that is driven by functionality. However in the course of research (funded by the Indonesian Ministry of Research Technology and Higher Education in the form of an overseas post graduate studies scholarship) into the design of a sustainable fishing vessel, it became apparent that the visual characteristic of the design had greater significance than anticipated. The vessel was to be used for operation in the inshore fisheries of eastern Java, where the traditional boats are striking in their dramatic shape and ornamentation (Figure 1). As an exercise in engineering design a low technology fishing boat of under 15 meters length for operation in the developing world (implying a low labour cost economy), is a straight forward challenge for a naval architect, and has little technical complexity.

Figure 1. An example a traditional Indonesian fishing vessel of eastern Java.

However despite the apparent simplicity of the task, evidence from earlier initiatives indicated that new vessel designs were not readily accepted by the operators. The research revealed that although the technical challenge involved in designing a new fishing vessel was straightforward, there was a parallel challenge associated with the cross-cultural nature of the task that could only be resolved by giving prominence to the appearance of the vessel. Exploring the issues relating to aesthetics for this specific case led to insights into their role in the general context of engineering design.

2 PRIORITISING AESTHETICS IN ENGINEERING DESIGN

At the outset of a design exercise the list of requirements that could be considered and prioritised might start with cost, and then take in such things as safety, weight, size, efficiency, reliability, ease of production, and ease of maintenance. The requirements might also include elements relating to human factors such as limits on temperature, noise and vibration, or others relating to habitability and comfort. But for a design exercise that is driven by functionality, aesthetics need not be mentioned – after all, what unambiguous and verifiable metric can be used to specify a requirement for beauty?

This neglect of the physical appearance of the designed object is not the case for all engineered products. The field of industrial design is dedicated to the interaction of the product with people, with both ergonomics and aesthetics being central to the success of the design. For products that are to be mass produced and sold into a competitive market, an elegant form can be perceived as an indicator of quality, and the desirability of the product enhanced by the tactile and visual pleasure experienced by the user. The Apple Corporation, with its range of products derived from the i-phone, are a remarkable example of the power of aesthetics for a mass produced product, and in the automotive industry style is a significant driver of a design.

This paper is reporting on research undertaken in the marine context, so the relevant designed products are ships and boats of all types and sizes. Although the vast volumes associated with the production of smart phones and cars are not found in this sector, recreational craft can be produced in the hundreds and so, just as with cars, successful sales may depend on attractive styling. Even with much larger vessels that are made in small batches of two or three, if they are being sold into a highly competitive market the advantage of product differentiation derived from a visual appearance that is associated with a distinct brand can be significant. This can be seen in recent years with the success of the X bow concept, a patented hull form that has been adapted for a variety of vessel types (as found on the Innovation pages of the Ulstein Group website in July 2017), one example of which is shown in Figure 2. Claims are made for the performance advantages of this bow form, but even disregarding this technical aspect of the design it is evident that a marketing success has been achieved due to the strikingly different aesthetics which distinguish these vessels from other functionally similar craft with conventional bow shapes.

Figure 2. An offshore supply vessel with patented X Bow, a style that has created a strong brand identity (Designed by Ulstein Group, www.ulstein.com)

The examples given above all have appearance as an important element of the design, but in every case this is an element of the marketing strategy, and the purpose of enhancing the visual appeal is to gain a competitive advantage. There are however one-off products where appearance can dominate all other considerations for different reasons, and examples of these can again be found in the maritime sector. Luxury mega yachts, which are high powered floating recreational palaces for the extraordinarily rich, are ordered and owned essentially as a demonstration of wealth, and so the visual impression and on-board experience drives a designer to ensure that this statement is made boldly and clearly. As a result appearance becomes more important than many other considerations. Similarly passengers on cruise liners, even if not at the extreme end of the wealth scale, are in part looking for confirmation of their success, and so both the external impression and the visual impact of the internal accommodation and recreational facilities have to be considered in detail. In the case of cruise liners stylists and interior designers are contracted to work alongside naval architects and marine engineers to ensure that aesthetic and engineering decisions are linked (Montgomery 2015). With mega yachts the roles may be even be reversed, so that it is the engineers who are contracted in to provide support to the project. Design credit is given to those who are primarily responsible for the external and internal appearance of the vessel (as evidenced in "The Fifty Most Beautiful" [2015]), these being designers who often do not have a formal education in naval architecture, but who have a background in industrial design or other creative disciplines, including fine art.

The discussion above demonstrates that examples can be found where the ultimate users of the product

dictate that appearance must take a high priority. But what of the many engineering products where the design is driven by cost, and this is itself derived from efficiency and effectiveness? In some cases the client providing the design requirement may not be the operator directly engaged with the product, but desk based and remote from the built artefact itself, and so have no personal interest in the issue of appearance. Examples of such cases, again from the maritime sector, are cargo ships such as bulk carriers or oil tankers, dredgers, offshore supply vessels, and fishing boats. In such examples of engineering design, the visual impact of the design is only considered informally while optimising the explicitly stated requirements. In the formal procedures aesthetics are neglected, as evidenced by the established models of the design process found in the theoretical texts on engineering design. There is no spoke on the common presentations of the design spiral, nor a box in the established higher level models of design philosophy (see summaries in Birmingham et al, 1995), that is labelled 'aesthetics'.

3 BEAUTY IN ENGINEERING DESIGN

Beauty is a word that can make engineers uncomfortable. It is not just that there is no metric by which to measure it, after all 'engineering judgement' is used to make decisions based on experience rather than hard data. The difficulty is that most engineers would consider themselves untrained and unqualified to make a judgment as to whether the design 'pleases the aesthetic senses, especially the sight' (*Oxford Dictionary* 2017), or 'exalts the mind or spirit' (*Merriam-Webster* 2017), these both being elements of formal definitions of 'beauty'. Where such judgement is an important element of the design process the decisions are contracted out, as indicated in the examples discussed above where interior designers or stylists collaborate with the engineers. In other cases the engineer can fall back on the long established principle that 'form follows function'. This phrase was first coined by Sullivan (1896) when referring to the natural world in the context of the architectural form of sky scrapers. The concept permits the designer to abdicate responsibility for the appearance of the product, the justification being that if the product is functionally successful then its form is inherently correct too.

The idea that the appearance of an object will be pleasing if its shape (form) is dictated by what it has to do (function) has been extended into the concept of 'functional beauty' (Sheridan 2014). The analysis of functional beauty suggests that it has two parameters which in essence are the degree of refinement of appearance, and the degree of refinement of function, although Sheridan uses longer terms, the former parameter being 'Knowledge of function', and the latter being 'Purity in aim and elegance.' Any design can be mapped into the design space shown in Figure 3 (which extends the thinking of Sheridan [2014, 74]) with designs that do have 'functional beauty' being both familiar and efficient. Inspection of the diagram shows that designs could be unsuccessful with respect to functional beauty due to being insufficiently or excessively refined in either of the parameters of function or appearance:

- Insufficiently developed functionality is self-explanatory, but at the extreme the object just doesn't work.
- Excessive refinement of function is less intuitive, but it is possible that an object is extremely effective, but at such cost that it is no longer appropriate. It is not fit for purpose as it is not optimally efficient. It is interesting that Sheridan terms such a failing as 'elegant', although 'over engineered' is more fitting.
- Insufficient attention to appearance could result in a design that is so far from the expected form that the object is unrecognisable.
- Excessive refinement of appearance can result in the standard form being abstracted (or 'codified' in Sheridan's terms) to such an extent that it is unusable. An amusing example of this type of failing is the hotel shower fitting that looks striking, but proves impossible to discover how to make it work.

While Sheridan's analysis of functional beauty draws on philosophy and psychology using language that is unfamiliar to the engineer, the concepts are readily grasped if reinterpreted with the more accessible terminology introduced in Figure 3, and the conclusion that a good design is both recognisable in terms of function and is fit for purpose, is obvious to the engineer. However this analysis does also provide additional insights into how a design can fail aesthetically, and so takes the engineer beyond the platitude that 'form follows function.'

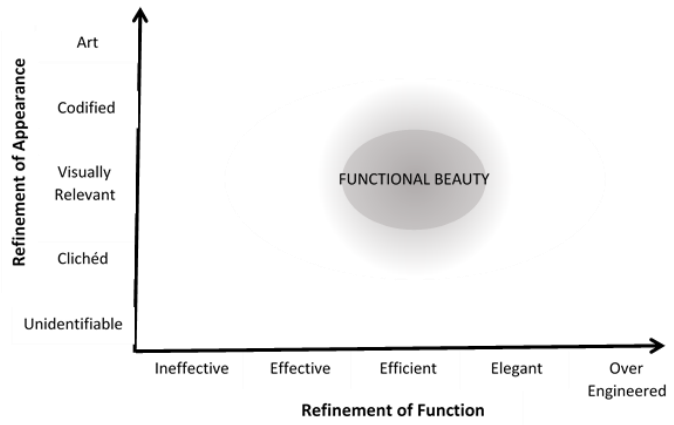

Figure 3. The parameters of functional beauty (after Sheridan 2014)

4 CONFLICTING CULTURAL NORMS

The concept described above need not cause any difficulty for the engineer, as it provides straight forward guidance that points the way to a satisfactory solution that has 'functional beauty'. Like the philosophy that form follows function, it makes no reference to style, nor does it require judgements as to whether as solution will 'please the aesthetic senses'. In fact, like many theories of design, this concept is as much describing practice as providing guidance. Many successful engineering designers who have never heard the term 'functional beauty', would say that the diagram in Figure 3 simply indicates what they strive to do. However the research underlying this paper, in part based on fieldwork in Indonesia, has led to a questioning of the adequacy of this approach in some situations, especially when there is a cross-cultural element to the problem.

The objective of the research was to develop a sustainable fishing vessel for the small scale fishers of Indonesia, this country being second to China in the scale of its capture fisheries (FAO 2016). It is estimated that there are over 640 thousand fishing vessels with 2.7 million fishers (MMAF 2014) directly employed aboard these vessels, and many more people working in related onshore activities. Amongst the fleets of locally built wooden vessels there are a small minority of craft that are built of fibre reinforced plastic (FRP), many of which have been provided to the communities in a series of initiatives by the Indonesian government or international agencies. However the success of these projects has been variable and further plans to continue such projects fiercely debated (Wibawa 2016, 5-6). Surveys undertaken by the authors demonstrated why this type of support for the fishing communities has been so controversial as it was observed that while some of these donated vessels were widely used, others were quickly abandoned. These rejected vessels could be found unused in remote corners of fishing harbours, even when they were only a few months old. The fact that both successful designs, and those that were not adopted, had significant technical variations from the locally built vessels indicated that it was not the imposition of unfamiliar technology that was the barrier to acceptance. The most obvious example of the introduction of an innovative technology was the use of fibre reinforced plastic (FRP) as the construction material. FRP inevitably introduces problems for the operators as it is difficult to modify and repair when compared to the traditional wooden vessels. Yet despite this difficulty examples could be found of FRP craft which were widely adopted (Figure 4) as well as examples where they had been rejected (Figure 5). While it is possible to identify elements of the failing designs where the operators' requirements have only been partially met, of greater significance is the fact that the successful designs emulate the shape and form of the traditional vessels, while the unsuccessful designs contrast strongly and present an aesthetic style that can be characterised as 'modern' or 'western'. The authors recognise that the failure to adopt innovative technology in the development context could be due to many issues including those associated with training, maintenance, ownership, and infrastructure, and also recognise that ways to address these issues could include ensuring that appropriate technology is employed and that stakeholder engagement is strong. However in this paper it is the significance of the appearance of newly introduced technology that is being considered.

Figure 4. Fibre reinforced plastic (FRP) boats of a type initially provided as aid after the 2004 tsunami have been widely adopted, and continue to be built on a commercial basis.

Figure 5. An example of a relatively new FRP fishing vessel that has been abandoned.

The observed lack of acceptance of 'western' looking vessels contrasting with the enthusiastic adoption of vessels that followed the Indonesian style led the authors to consider the role of aesthetics in the context of technology transfer, and to propose the hypothesis that a cultural mismatch can be a significant barrier to

the adoption of technology. Set in the maritime context, with the design of fishing vessels as a specific example, the argument can be expanded as follows.

If a consultant from the developed world were engaged to design an improved vessel for the developing world, the focus of the naval architect would tend to be on the economic, operational and technical requirements. The issue of appearance might be ignored on the premise that form follows function, however despite this there will still be an unconscious bias toward a solution that looks 'right' to the consultant. The result will be one that presents the consultant's own preferences of what is aesthetically pleasing but, more significantly and almost unavoidably, it will reflect the norms dominant in the consultant's own culture. This will not be a considered decision, it will simply embody the consultant's belief as to what a fishing vessel should look like. Imagine however if the geographical direction of the flow of expertise were reversed. Imagine trying to persuade fishermen from the north of Scotland (or Norway, or Canada) that a boat with the most up to date technology was available to them, but it looked like the vessel in Figure 1. No matter how big the subsidy offered, even 100% of the cost, it is highly improbable that the fishermen would be willing to take ownership of such a vessel. The cultural gulf demonstrated by the appearance of the vessel is just too great to bridge. This however is what is being done when an expert from the developed world proposes to introduce a 'better' solution into a developing world context – the cultural gulf, the mismatch, can be such a significant barrier as to make the new technology unacceptable.

5 OVERLAPPING CULTURES

The discussion above simplifies cultural differences, presenting an artificial case where two cultures are entirely alien to each other. In practice, in the digitally connected and in many aspects globally unified world of the 21st century there is an interchange of cultural values, and an overlap of norms. Indonesian boats can be seen decorated with the insignia of the football clubs of the European leagues, Figure 6, just as in many parts of the developed world *satay*, the Indonesian dish, is enjoyed when dining out. In addition in many situations designers do not have to conform to cultural norms, but make it their purpose to change perceptions, the world of fashion being the prime example of this. Marketing in any field is partly about discovering what the customer desires, and partly about convincing them that an alternative is even more desirable. However, in the case of promoting economic development through the transfer of technology, trying to drive a change in aesthetic values (either deliberately or unconsciously) is unnecessary and may obstruct achieving the primary objective. So rather than creating an additional potential obstacle to the successful introduction of new ideas, the designer should try to align the appearance of the proposed design with the prevailing culture. The difficulty of achieving this when the engineer is an outsider, operating in the context of an unfamiliar culture, should not be underestimated. The important cultural elements are not necessarily the obvious flamboyant ones, but subtle and obscure details that are difficult to identify. In addition, while a consultant may be unaware of how their own culture could be influencing and impacting on their decision making, so the customer may be unable or unwilling to express the cultural imperatives of their world. This could be because the specific details are in their eyes so obvious as not to be worth remarking on, or it could be because they are religious or spiritual in origin (Parastu, Sudamarwan, and Budiarta 2013), as shown in Figure 7, and any explanations might be considered difficult or inappropriate.

Figure 6. Evidence of cross cultural influences, here European football club insignia being used as ornamentation.

Figure 7. Examples of ornamentation that have regional or religious significance.

6 BALANCING THE COSTS AND BENEFITS OF BEAUTY

The insights, discussed above, into the role of aesthetics in engineering design emerged from research into the design of fishing vessels in the developing world, where it was realised that unless proper attention was given to the appearance of the design the proposal was at risk of being rejected by the operators however good the technology might be. Other benefits of raising the priority of visual appearance were then recognised that were universally applicable, including the potential for gaining a marketing advantage by generating a brand identity, and the greater satisfaction and loyalty generated in the operators if they could have pride in their vessel or equipment. It could even be argued that such pride might be translated into an enhanced attitude to health and safety.

Although it is clear that there are benefits from considering aesthetics in a design, in a commercial context this has to be balanced against cost. However in many cases there is no need for a good looking design, even a beautiful one, to be more expensive than a utilitarian or ugly one. To understand this the concept of 'satisficing', first proposed in 1969 by Simon (1996), needs to be revisited. Simon pointed out that although optimisation techniques are used throughout the design process, the final result is not an optimal one, but one that satisfies the design requirements. The optimising process stops once the requirements are met, as to continue would be an unnecessary expenditure of resources. However if Simon's idea of satisficing is considered further it can be seen that this process leads to an unexpected conundrum. Unlike the result of optimisation, satisficing does not lead to the inevitable single solution, but to one of a multitude of solutions all of which should be equally acceptable, as all would satisfy the design requirements. Although in theory all such solutions are equally good in practice the customer, if given a choice, would be able to indicate a preferred design.

Such a preference is not captured in the design requirements, but it would reflect the customer's priorities. When making design decisions compromises are traded. All of the many possible solutions balance these compromises differently, but given a choice the customer would be able to recognise which most closely reflects their values. For the designer to develop a design that will respond to the customer's values, it is necessary for them to be aware of the customer's priorities. If the design process starts with the elements that are most important to the customer, and the customer's priorities are considered every time a decision that requires compromise is made, then the result of the satisficing process will be one that reflects the customer's values. Optimisation processes are often explained by the analogy with climbing a hill, where the objective is to find the summit. Satisficing only requires that a predetermined altitude be reached, but the point where the optimising search process reaches that contour is defined by the point at the bottom of the hill where the climb starts. If the designer can start in the right place, then the result is more likely to respond to the customer's priorities and values.

While this principle applies to all the technical elements of a design, the customer will also have aesthetic values derived from personal taste and from the norms of their culture. As with technical aspects, if the style of the product is established at the outset, and appearance set alongside other considerations when each design decision is made, then the satisficing process will produce a result that reflects an aesthetic preference. While aesthetic considerations should not disrupt function or safety (Brewer, 1994) in many cases the technical design decisions do not relate to geometry and appearance, or at least only in a general way, so this aspect of the decision can be guided by aesthetic preferences with no impact on the technical outcome. If all else is equal, and if the design requirements have been satisfied then all else really is equal, the customer would prefer a design that is in their eyes beautiful.

7 EMBEDDING AESTHETICS IN ENGINEERING DESIGN THEORY

In developing a sustainable fishing vessel for operation in the waters of Indonesia, the authors' research led them to recognise that the vessel's appearance could be crucial to acceptance of proposed technical innovations. The technology had to be packaged in a form that was familiar, even appealing, to the operators. Responding to this concern became a significant part of all stages of the design process. Aesthetic considerations were integrated into all of the following: the requirement elicitation process; the interpolation of data from existing 'basis' vessels; and the evaluation of proposed designs (by referring to focus groups of fishing vessel skippers, as described in detail below). This extended process resulted in a design that contained all the technology identified as appropriate for a sustainable fishing vessel in the Indonesian context, but also one that would look at home in the fishing ports of the region, and so would be admired and desired by the fishers who would operate it.

Reflecting on this practical implementation of a design process, where aesthetic considerations have been given a high priority, can provide suggestions as to how this often ignored aspect of engineering design could be formally embedded into the design process in other situations. In exploring the role of aesthetics we can follow the terminology of formal optimisation as defined by Sen and Yang (2012, 18). In this interpretation of design the criteria are stated as objectives, each of which links an attribute to a required direction. For example the attribute 'cost' must be low, so

the direction of the design process is to reduce this, while the attribute 'stability' (for a fishing vessel) must be high, so the direction is to increase this. If there is a specified threshold value to be achieved for the result to be accepted then the objective is considered a 'constraint', however if it is simply an aspiration to achieve the best possible result the objective is termed a 'goal'. In the examples just mentioned, stability is a constraint if it is specified that it must meet the requirements of regulations, while cost is a goal if it is simply required to be as low as possible. In these terms if appearance is included in the criteria for a design then this objective can be categorised as a goal, specifically to make the design as aesthetically pleasing to the customer as possible.

Design theorists usually resort to diagrammatic representations of the design process, and these models are as numerous as there are theorists. While not intending to introduce another model, it was noted earlier in this paper that aesthetics are neglected in many such models for engineering design so it is interesting to consider how this element could be incorporated. A widely accepted graphical interpretation of design at the strategic level is that of a spiral, indicating that each sub-problem in the design process has to be returned to iteratively until the requirements are satisfied. Versions of this model exist for different engineering sectors, and in the marine field such a visualisation of the process was first proposed by Evans (1959, 671-678). Other authors subsequently devised modified proposals to emphasise specific elements of the process such as the economic evaluation (Buxton 1987, 78), or to accommodate particular vessel types such as yachts (Larsson and Eliasson 2014, 5). While acknowledging that the spiral model is a huge simplification of the complexity of the activity of design, it has proven its value in communicating the nature of design to students and aspiring designers. As the spiral effectively facilitates a greater understanding it may be helpful to identify where aesthetics could be explicitly indicated in this model of the process.

The design spiral has two components, the circular loops indicating one complete cycle of the design process, and the radial spokes indicating sub problems that have to be addressed. Visualisation of the proposed design is an integral part of many of the sub problems, as producing a graphical representation of most elements of the design is an essential part of formulating a solution. However creating a drawing does not automatically imply that aesthetics have been taken into consideration.

Figure 8 presents a simple design spiral with aesthetic decision making explicitly identified in the design process. As can be seen aesthetics are considered in two ways. Firstly there is a dedicated 'spoke' added to the spiral at an early stage. This indicates that the 'style' and overall impression of the product should be explored (in sketches) at the very start of the synthesis process, and that this initial conjectured solution should be revisited in subsequent iterations as more detail is generated. It is interesting to consider the positioning of aesthetics in this respect, and to contrast it with other design goals, such as safety and cost. While all three, (aesthetics, safety and cost) provide a 'direction' for design decisions throughout the process, the latter two are essentially evaluated at the end of each iteration of the process, while aesthetics is considered at the beginning, so providing a visual template into which other decisions try to fit. Secondly Figure 8 shows that one of the loops of the process could also be considered as an aesthetic iteration. Although the concentric loops of the spiral are not usually explicitly identified, the outermost one is dedicated to establishing the value of the principal parameters of the design, so producing a symbolic model that defines the product only in terms of numbers (things like size, weight, capacity, power etc.). The next iteration is a visualisation one, where the symbolic model is turned into an iconic model in the form of sketches of what the product could look like. This is where aesthetics can again be seen to be considered explicitly, ensuring that of the many possible geometric forms that could satisfy the numerical requirement, a geometry is selected that also conforms to the aesthetic preferences of the customer.

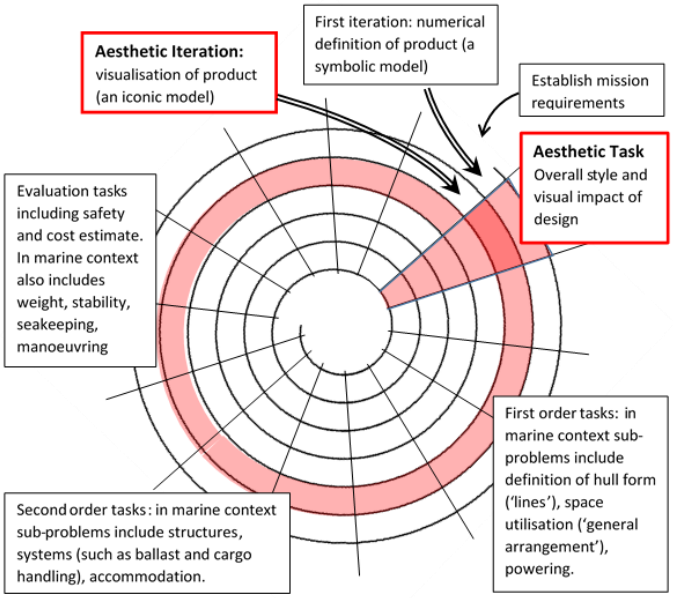

Figure 8. A generalised design spiral, with aesthetics explicitly indicated.

8 AESTHETICS IN ENGINEERING DESIGN PRACTICE

Designers sketch possible solutions at the very earliest stages of the design process, conjectured from imagination and prior experience, or by adapting established solutions. While sketching every designer will

be making choices based on what is considered to be the desired appearance, though it is possible that the designer will perceive the result an inevitable outcome of form following function. However in the light of the discussion above it is possible to consider the way that these decisions regarding appearance can be taken, as this is affected by the cultural context of the design activity.

In most cases the designer will be operating within a culture that is entirely familiar, which implies that the aesthetic values of the designer (their taste) aligns with that of the customer. Even without any explicit discussion as to appearance, the designer's instinct will be met with a favourable response. However even in this situation the designer does have a choice, which is either to stay safely within the conventional norms, or alternatively to step outside accepted solutions and introduce an imaginative or innovative proposal. In the former case the designer could be said to be following fashion. In the marine context this is achieved by consideration of the geometry of a number of basis vessels, then by scaling the dimensions using methods such as those suggested by Larsson and Eliasson (2014), to arrive at a proposal that is entirely in keeping with other vessels of a similar type. However in the latter case, where the designer proposes to introduce a design that is in appearance at variance from the established ones, the designer must have confidence that they are so familiar with the product, and so knowledgeable of the customer's aspirations and ambitions, that they can propose a solution that the customer will recognise as being just right despite its unusualness. If this is successful the client will be delighted that the proposed design exceeds expectations, and is evidence that the designer is so in tune with trends that they can lead fashion rather than follow it. This is clearly a risky strategy, but where marketing suggests that product or brand differentiation is beneficial, then this is necessary.

The contrasting situation, and the one which instigated this exploration of the role of aesthetics in design, is where the designer is working in an unfamiliar cultural setting. The design will provide an innovative technical solution in an area where the designer has recognised expertise, but the product will be operated in a cultural setting greatly contrasting from the designer's own. In this situation the risk of providing a visually innovative solution is great, as the designer may unwittingly present something that is at the very least unappealing to local taste and alien to cultural norms, and at worst offensive to religious or cultural sensibilities. Innovation theory suggests that new ideas should be introduced gradually in order to minimise the risk of failure (Abernathy 1988), so while technological innovation may be the purpose of the design exercise, introducing an innovative aesthetic adds unnecessary risk, so the designer should as far as possible maintain the appearance of the existing solutions. This situation is an extreme case of the method described above as 'following fashion', but here the designer must set aside their own preferences and tastes, and follow un-critically the norms identified from the existing solutions.

In the case of designing a fishing vessel for Indonesia, it was necessary to first select from the many contrasting vessels and regional variations (Samodra 2009) an appropriate vessel type that was extensively operated in the relevant area. In this case the *paying*, a boat type commonly operated out of Muncar and other ports of eastern Java was selected. The fleet was analysed in detail by considering the geometry of a selection of basis vessels and from this the expected dimensions and proportions of the craft were identified. This numerical analysis of the geometry included all significant visual features such as shape and angle of the bow and stern, the curvature of the deck line, the position and proportions of the cabin, and position and height of the mast. In addition relevant stakeholders, such as skippers, crews and owners, were engaged with at the outset of the process by using questionnaires and interviews (Figure 9).

Figure 9. Questionnaires and in-depth interviews were conducted with stakeholders in their own environment, here with a fishing vessel skipper and crew member aboard their boat.

Figure 10. A focus group of stakeholders using scale models to evaluate alternative desigmn proposals.

It is quite possible to process the data from surveys of existing designs and still arrive at something that many would agree is ugly. However there are fundamental aesthetic considerations which are explored in the fine arts and in graphic and industrial design and which reference ancient cultures as their sources. These aesthetic principles are rarely explored in the engineering design context, however in the marine field the work by Guiton (1971) provides some analysis of what is effective in the context of ships and yachts. While it is not proposed to enlarge on this here, it can be noted that in considering the overall impression of the vessel Guiton emphasises the importance of conformity of lines (converging on focal points for example), and of the shape and proportions of the visual envelope, or overlapping envelopes, in which the design is contained. When developing the fishing vessel for Indonesia the authors used these principles in conjunction with the numerical data derived from basis vessels and the qualitative information elicited from the stakeholder interviews. (In doing this the authors assumed that these aesthetic principles are not a uniquely western convention, but are universal and can be applied in any culture, however it is recognised that further interdisciplinary research is needed to explore this.)

The stakeholders were referred to again toward the end of the design process when focus groups were organised to provide a critical commentary on the proposed designs (Figure 10). All the stakeholders participating in these groups brought valuable experience and knowledge to the sessions, however recognising that many had limited formal education, and as a result limited literacy and ability to interpret technical drawings, scale models were used to communicate what was proposed and to facilitate discussion, as can be seen in Figure 10. This close involvement with the operators, combined with the analysis of the geometry of basis vessels, was considered essential in order to avoid introducing or omitting visual elements to the proposed solution that, although unremarked by the designers, were of significance to the operators. The entire design process is detailed by Wibawa (2016) with the resulting design shown in Figure 11, and a computer generated visualisation shown in Figure 12.

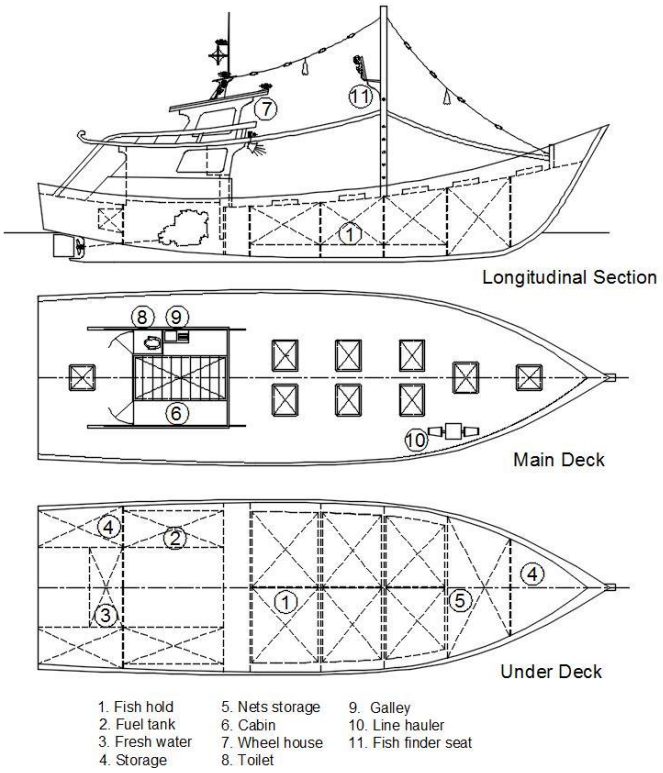

Figure 11. Drawing of the final design for a sustainable fishing vessel for the small scale fisheries of east Java, Indonesia.

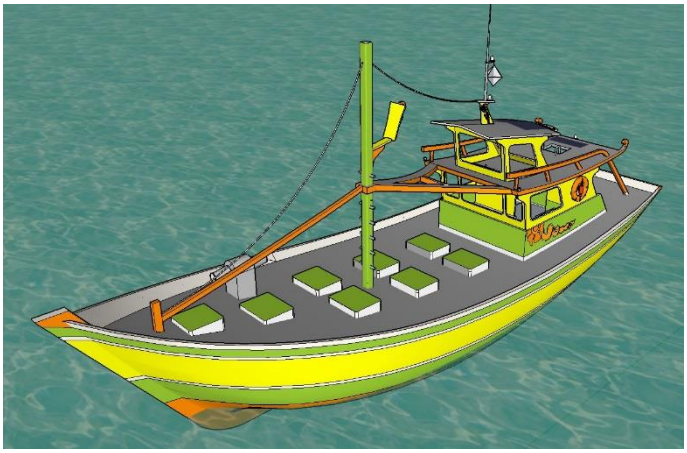

Figure 12. Visualisation of the fishing vessel design.

9 CONCLUSION

In engineering design the effort to develop a product that is efficient and profitable, with multiple design drivers that can include ease of manufacture, ease of maintenance, a minimum carbon footprint, maximum recyclability, and conformance with relevant regulations, it is unsurprising that appearance is often considered irrelevant, implying that aesthetics has no significance in the design process. However insights into the role of aesthetics was an unexpected outcome of combining research into the traditional fishing vessels of Indonesia with the challenge of designing a small sustainable fishing vessel for operation in the coastal waters of eastern Java. During the research it was observed that in a cross cultural context simply producing a good technical solution did not guarantee acceptance by the intended operators. If the appearance was not sympathetic to cultural norms and to the fishers' expectations of what looked appropriate then this would create a barrier that could result in appropriate technological innovations being rejected. Reflecting on this it was realised that benefits can be gained in other situations if a design is visually pleasing, such as market or product differentiation and more highly motivated operators. However of greater significance was the realisations that aesthetic decisions are continually being made during the design process, even

if these are not conscious decisions but simply a reflection of the designer's personal preferences and cultural conditioning.

If it is accepted that aesthetic decisions are unavoidably being made, even if unconsciously or by default, and also that good aesthetic design can have direct benefits, then it is important to recognise that enhancing the appearance of a proposed design need not have resource implications. In many cases there are numerous geometries that will provide equally good technical solutions, so identifying a geometry that evokes pleasure, or even one that 'exalts the mind or spirit' (to quote again the dictionary definition of beauty [Merriam-Webster 2017]) need not cost more. Establishing what is pleasing to the eye in a cross-cultural context can be a significant challenge, overcome by close engagement with all the relevant stakeholders. In a more conventional setting identifying the stylistic and visual preferences of the client should be part of the requirement elicitation process, with the result that from all the possible solutions that would satisfy the technical requirements, the final proposal is one that also visually delights.

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